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EVALUATION OF PROTOTYPE AIR/FLUID SEPARATOR FOR  
SPACE STATION FREEDOM HEALTH MAINTENANCE FACILITY

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PURPOSE:

To evaluate a prototype air/fluid separator suction apparatus proposed as a possible design for use with the Health Maintenance Facility (HMF) aboard Space Station Freedom (SSF.)

OBJECTIVES:

- Evaluate the effectiveness and efficiency of the prototype design at producing medical-quality suction for a variety of types of fluids (representative of body fluids.)
- Evaluate the effectiveness and efficiency of the prototype design at separating the fluid collected from air in the collection system.
- Assist in defining the functional and performance requirements and feasibility for the HMF Air/Fluid Separator through use of the prototype in zero-gravity (0-G.)

OVERVIEW:

A KC-135 parabolic flight test was performed on May 2, 1990 with the goal of evaluating a prototype suction apparatus and air/fluid separator in microgravity. The flights followed the standard 40 parabola profile with 20-25 seconds of near-zero gravity in each parabola. Four investigators were involved with the study.

The study was performed using a prototype developed by Dr. Bruce Houtchens under contract with KRUG Life Sciences. The prototype represented the evolution of several designs and was known to have difficulty with air/fluid separation in some modes of operation. (Data from Dr. Houtchens' investigations are pending at the time of this report.)

The investigation team prepared a protocol to evaluate the device in several regulator modes (or suction force), using three fluids of varying viscosity, and using either continuous or intermittent suction. It was felt that a matrixed approach would best approximate the range of utilization anticipated for medical suction on SSF. The protocols first were performed in one-gravity in a lab setting to familiarize the team with procedures and techniques. Identical steps were performed aboard the KC-135 during parabolic flight.

The prototype was found to function fairly efficiently (although not 100%) at the high regulator settings for the fluids of lesser viscosity. Lower suction settings produced less efficient air/fluid separation. In 0-G at altitude the suction was not strong enough to pull the higher viscosity fluids into the apparatus.

The study concluded that the concept of combined suction and air/fluid separation is feasible for medical use on SSF, but that further design development is needed to improve efficiency in function and performance.

#### **BACKGROUND:**

Current plans for crew health care aboard SSF call for the capabilities to perform minor surgical procedures, advanced life support, trauma management and airway support. All of these capabilities require the provision of medical suction ranging from low intensity (5-10 mm Hg) to high intensity (250 mm Hg) and may include either constant or intermittent suction flow.

Due to the fact that SSF will be a closed system with regards to life support, the utilization and reprocessing of valuable resources (air, water) becomes a critical issue. Minimizing volume for waste stowage and protection of the SSF environment from contamination are equally important concerns. Therefore, there is a need to carefully contain suctioned waste fluids while returning any air collected back to the environment (both to reduce stowage volume and to recirculate the resource).

To meet these needs, the HMF requires equipment that will function both in providing variable suction for a variety of sources and for producing air/fluid separation. In 1988 Dr. Houtchens initiated some investigations into possible design solutions for this equipment and delivered a prototype for the air/fluid separator in April 1990.

#### MATERIALS:

1. Houtchens Prototype Air/Fluid Separator
2. HMF Medical Restraint System (MRS) (prototype)
3. Bags and containers for various fluids, all marked for quantities
4. Straps, cords, tubes, attachments, clamps, markers
5. Pre-mixed fluids placed in containers
  - Colored water (low viscosity)
  - Whole milk (medium viscosity)
  - Chocolate pudding (thin) (high viscosity)
6. Clean-up materials (towels, water with clorox)
7. Recording materials (VHS video, still photography, written notes)

#### PERSONNEL AND SUPPORT:

Four investigators were involved; three operated the equipment as a team and one served as the video recording technician. Still photography was provided by a non-dedicated NASA photographer.

#### TEST PROTOCOL:

1. All procedures were performed first in the HMF ground lab for familiarization. The fluids were pre-packaged into measured IV bags or see-through plastic jugs. Receiving containers were either empty IV or foley catheter bags that were pre-labeled and clamped shut (so that the only volume in the bag would come from the air/fluid separator.)

2. During the flight there was only sufficient time to accomplish the specific protocols. General observations were made during flight, but the actual measurements were performed after return to ground. The receiving bags were carefully labeled, clamped-off and placed in ice-chests to insure accurate measurements after the flight.
3. The test protocol was as follows:
  - A. Evaluate the efficiency of air/fluid separation using continuous suction at different regulator settings.
    - set-up 10 numbered bags of 500ml colored water
    - attach bags to suction in sequential fashion
    - attach empty collection bags to output.
    - process the fluid through the air/fluid separator
    - A1 & A2: 60 mm Hg suction
    - A3 & A4: 100 mm Hg suction
    - A5 & A6: 140 mm Hg suction
    - A7 & A8: 180 mm Hg suction
    - A9 & A10: full suction
  - B. Evaluate the efficiency of intermittent suction and air/fluid separation using fluids of different viscosity.
    - use the most efficient regulator setting from step #A (above.)
    - set up two large bags for colored water and whole milk; set up two numbered receiving bags.
    - attach the suction to the large fluid bag and suction for a total of four 18 second parabolas using a 3 second cycle of on-off suction (using the suction finger valve.)
    - after test fluids, flush system into waste bag.

- C. Determine the volume of different fluids that can be suctioned continuously during a 20 sec. time and note the efficiency of air/fluid separation.
- use the most efficient regulator setting from step # A.
  - set up three jug containers for colored water, milk and pudding; set up six numbered receiving bags, use a suction catheter tip.
  - process the fluid through the air/fluid separator:
    - C.1 20 sec colored H<sub>2</sub>O
    - C.2 20 sec colored H<sub>2</sub>O
    - C.3 20 sec milk
    - C.4 20 sec milk
    - C.5 20 sec pudding
    - C.6 20 sec pudding
  - after test fluids, flush system into waste bag.
- D. Evaluate the efficiency of intermittent suction and air/fluid separation using different fluids from on open system.
- use the most efficient regulator setting.
  - perform intermittent suction of 3 second cycles using three 18 second parabolas for each type of fluid.
  - set up three jug containers for colored water, milk and pudding; set up 3 large labeled receiving bags; use suction catheter tip.

#### RESULTS:

- Evaluate the efficiency of air/fluid separation using continuous suction at different regulator settings (See Figure 1).

The efficiency of air/fluid separation increased with the higher regulator settings (higher suction force.) The full suction setting was therefore chosen for the remainder of the tests.

<u>Regulator</u>	<u>Fluid</u>	<u>Air</u>	<u>Avg. Efficiency</u>
60 mm	300 ml 500	110 ml 180	73.2%
100 mm	500 500	85 120	83.0%
140 mm	500 500	130 100	81.3%
180 mm	500 500	100 80	84.7%
full	360 480	20 20	94.8%

- Evaluate the efficiency of intermittent suction and air /fluid separation using different fluids (See Figure 2).

<u>Type of Fluid</u> <u>Efficiency</u>	<u>Fluid</u>	<u>Air</u>
18 sec X 4 of H <sub>2</sub> O	1800 ml 40 ml	97.8%
18 sec X 4 of Milk	1400 ml 60 ml	95.9%

Suction speed and volume was acceptable for medical purposes. Air/ fluid separation was accomplished with a ratio of 1:45 for water (efficiency of 97.8%) and 1:23 for milk (efficiency of 95.9%).

- Determine the volume of fluids that can be suctioned continuously during a 20 sec time and evaluate the efficiency of air /fluid separation. (See Figure 3).

The volume and rate of suction was acceptable for medical purposes for the first two fluids of lower viscosity. The higher viscosity fluid (pudding) was unable to be suctioned into the apparatus. The pudding under suction would advance into the suction tubing, but there appeared to insufficient force to bring the pudding into the air /fluid separator.

<u>Type of Fluid</u> <u>Efficiency</u>	<u>Fluid</u>	<u>Air</u>	
20 sec colored H <sub>2</sub> O	820 ml	10 ml	98.8%
	750 ml	10 ml	98.6%
20 sec whole milk	700 ml	20 ml	97.2%
	650 ml	15 ml	97.7%
20 sec pudding	0 ml	0 ml	

- Evaluate the efficiency of intermittent suction and air / fluid separation using different fluids in an open system (See Figure 4).

<u>Type of Fluid</u> <u>Efficiency</u>	<u>Fluid</u>	<u>Air</u>	
18 sec X 3 of H <sub>2</sub> O	1600 ml	50 ml	96.9%
18 sec X 3 of Milk	1420 ml	55 ml	96.3%
18 sec X 3 of Pudding	0 ml	0 ml	

Intermittent suction from an open system appeared to have sufficient volume and rate for medical purposes. Again, the higher viscosity pudding was unable to be suctioned into the apparatus.

#### DISCUSSION:

Prior to flight it was anticipated that this prototype would work less efficiently at the lower regulator settings. This was noticed in the one-G lab tests and was explained by Dr Houtchens to be due to the physics of the separator blade design. Dr Houtchens felt that this could be corrected in a next generation prototype he was working on.

The air / fluid separation functioned with reasonable efficiency at the higher regulator settings and provided sufficient suction to perform most anticipated medical tasks. It was felt that this accomplished the goal of demonstrating feasibility of the concept and program requirement for SSF Health Maintenance Facility.

The difficulty in creating enough suction to process the more viscous pudding aboard the KC-135 was felt to be secondary to the decreased atmospheric pressure during flight resulting in less efficient compressor function. (KC-135 flies at cabin altitude of 4,500 feet which is equal to approximately 12.5 psi. This effect has been noticed on previous KC-135 experiments by the flight crew.) If the SSF cabin pressure is reduced to 10.2 psi, this will need to be considered in the design of the HMF suction equipment.

#### RECOMMENDATIONS:

- It is recommended that the current HMF Systems Requirements for the Air/Fluid Separator be retained.
- It is recommended that should Dr Houtchens produce a further prototype of the Air/Fluid Separator, that it be re-evaluated in a similar manner.
- It is recommended that the issue of bladder drainage in zero-gravity without the use of extrinsic suction be evaluated. (i.e. Is the intrinsic pressure of the bladder enough to produce catheter drainage without the use of suction and without residual bladder volume of clinical significance.)



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FIGURE 1.  
Continuous Suction at Various Regulator Settings

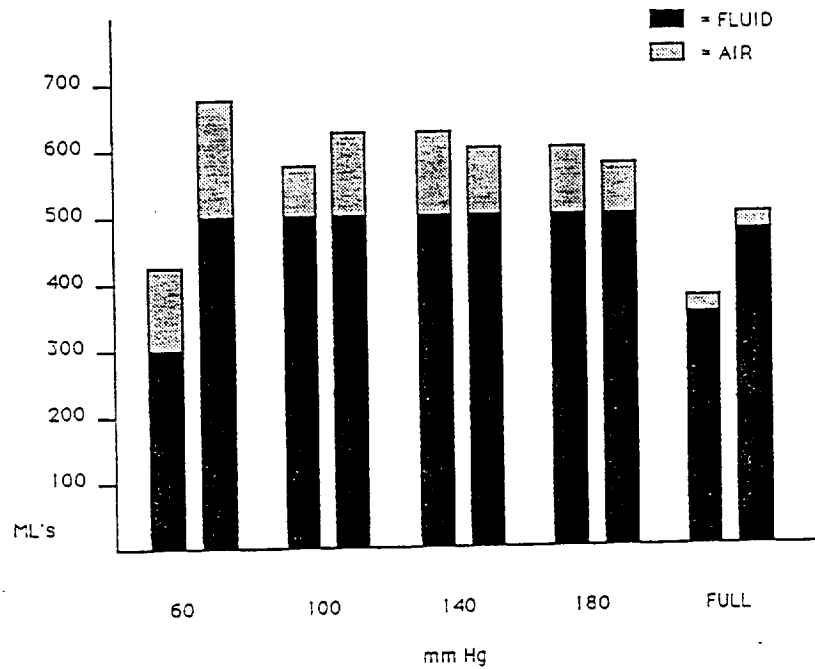


FIGURE 2.  
Intermittent Suction Using Different Fluids  
(18 seconds X 4 at Full Suction Setting)

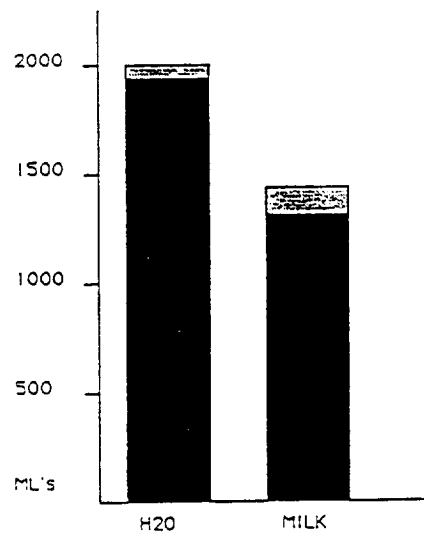


FIGURE 3.  
Continuous Section for 20 seconds  
at Full Regulator Setting

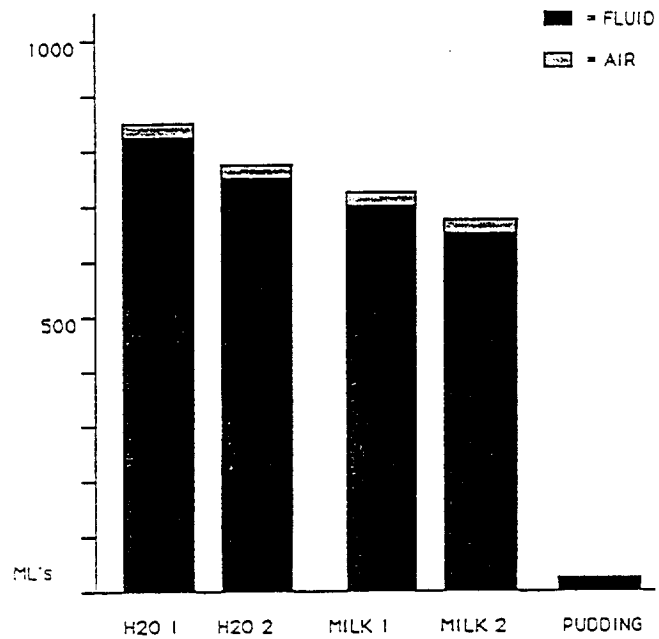
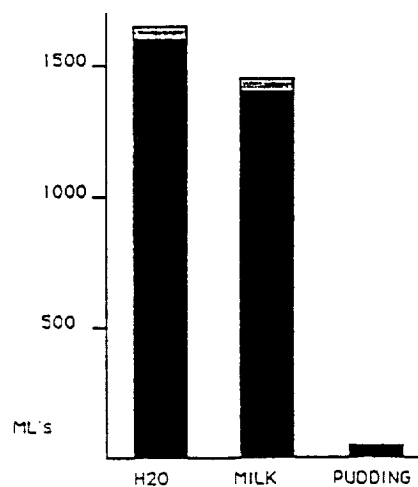


FIGURE 4.  
Intermittent Suction of Different Fluids  
From an Open System



#### NASA PHOTO REFERENCE

*S90-36941*

Collection of liquids for the air/fluid separator

*S90-36943*

Separation of air from various liquids

*S90-36946*

Collection of fluids from the air/fluid separator

*S90-36953*

Effects of 0-g on a flier

*S90-36956 - 58*

Containment of liquids from the air/fluid separator

*S90-36960 - 63*

Filling bags with fluid from the air/fluid separator

*S90-36966*

Separation of air from various liquids

